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Mapping the new molecular landscape: social dimensions of epigenetics

Martyn Pickersgill^a, Jörg Niewöhner^b, Ruth Müller^c, Paul Martin^d & Sarah Cunningham-Burley^a

^a University of Edinburgh, Centre for Population Health Sciences, Old Medical School, Teviot Place, Edinburgh EH8 9AG, UK

^b Humboldt University, Berlin, Germany

^c Lund University, Lund, Sweden

^d University of Sheffield, Sheffield, UK

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Martyn Pickersgill^{a*}, Jörg Niewöhner^b, Ruth Müller^c, Paul Martin^d and Sarah Cunningham-Burley^a

^a*University of Edinburgh, Centre for Population Health Sciences, Old Medical School, Teviot Place, Edinburgh EH8 9AG, UK;* ^b*Humboldt University, Berlin, Germany;*

^c*Lund University, Lund, Sweden;* ^d*University of Sheffield, Sheffield, UK*

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Epigenetics is the study of changes in gene expression caused by mechanisms other than changes in the DNA itself. The field is rapidly growing and being widely promoted, attracting attention in diverse arenas. These include those of the social sciences, where some researchers have been encouraged by the resonance between imaginaries of development within epigenetics and social theory. Yet, sustained attention from science and technology studies (STS) scholars to epigenetics and the praxis it propels has been lacking. In this article, we reflexively consider some of the ways in which epigenetics is being constructed as an area of biomedical novelty and discuss the content and logics underlying the ambivalent promises being made by scientists working in this area. We then reflect on the scope, limits and future of engagements between epigenetics and the social sciences. Our discussion is situated within wider literatures on biomedicine and society, the politics of “interventionist STS”, and on the problems of “caseness” within empirical social science.

Keywords: epigenetics; promise; novelty; social science; cancer; methylation

Introduction

As “omics” science proliferates and the complexity of biological systems becomes the overarching ontology in the life sciences, epigenetics has come to play an increasingly central role in today’s molecular landscape. Grants, infrastructure, patents, journals, and awards all form increasingly visible constituents of this field, helping to construct it as novel and important. Often regarded as a branch of genetics, epigenetics articulates with developmental biology, endocrinology, immunology, plant science, psychiatry, and other interdisciplinary domains. In epigenetics, changes perceived as salient when compared with more “traditional”

*Corresponding author. Email: martyn.pickersgill@ed.ac.uk

genetic approaches include an investigative focus on “what genes can’t do” (Moss 2003). In particular, research and theorization in epigenetics presents challenges to and enrichments of dominant strands of evolutionary theory and the widely instantiated (though not hegemonic) “gene-centric” model of life (Barnes and Dupré 2008; Jablonka and Lamb 2006). Epigenetics is claimed to be “one of the most promising and expanding fields in the current biomedical research landscape” (Rodríguez-Paredes and Esteller 2011, 330).

Research in epigenetics today is primarily concerned with the investigation of changes in gene expression, where the mechanism for this is something other than a change to the underlying DNA. The focus of research is on the dynamics of chemical modification upon the DNA, which enhance, decrease, initiate or silence gene expression. One of the key processes is methylation, the addition of a chemical compound called a methyl group to a DNA base. Biologists understand epigenetic regulation of gene expression as essential to organismal development, playing important roles in diverse processes such as cell differentiation and genomic imprinting (Feil and Fragga 2012). Epigenetic changes may be mitotically (or even meiotically) heritable – although how far this is or could be the case is still debated. Whilst, a decade or so ago, investigators emphasized the heritable aspect of epigenetic changes, more “recent definitions are less stringent” (Bohacek and Mansuy 2013, 221).¹

In spite of the expanding discourse of epigenetics, the term itself was first introduced over 70 years ago, within the realm of embryology: epigenetics is not, in many senses, “new”, and the ways in which it is constructed as novel speak to wider debates about the scope and nature of biomedicine. Biomedical researchers (and others, such as plant scientists) have come to invest both symbolic and material capital in epigenetics. As with some contemporary research in neuroscience (Pickersgill 2009), epigenetics represents “a concept, a horizon of research, and an assemblage of ideas and practices [that] brings the environment back into the postgenomic era” (Rapp 2011, 669). Accordingly, wet and dry laboratory findings exhibit a certain amount of “interpretative flexibility” (Pinch and Bijker 1984) that lend themselves well to inclusion in the ontological projects of a range of actors. These include practitioners of spiritual healing and environmental activists interested in the relationships between minds, bodies and societies, as well as social scientists. Whilst sustained attention to epigenetics from anthropologists, sociologists, STS scholars and bioethicists has been lacking, “corridor talk” – that “key means of intellectual (re)production” (Downey, Dumit, and Traweek 1998, 245) in the social sciences – has begun to embed promises and expectations about this field.²

Our aim in this article is to sketch out some of the biomedical, social scientific, bioethical and public dialogue around epigenetics, in order to locate the various considerations and concerns that are being figured as salient in regards to this field. Our position derives from a range of documentary analysis, participant observation and observant participation at various meetings and events pertaining to epigenetics, and a laboratory ethnography (conducted by Niewöhner). Throughout,

the article is grounded by our sense that first, as an area of increasing interest within biology and medicine some examination of epigenetics by STS scholars seems warranted; and second, epigenetics proves a useful case for exploring some of the debates currently being played out across different realms of STS in regards to the diverse roles played by social scientists within technoscientific innovation.

Towards biomedical novelty

The term “epigenetics” was first coined by embryologist Conrad Waddington in his 1940 book, *Organisers and Genes*; famously, this involved the metaphor of the “epigenetic landscape” to characterize the different ways in which environmental circumstances could influence gene expression and consequently modulate development. Early twentieth-century epigenetic theory “conceived the organism as a product of the reaction between a particular kind of protoplasm, whether in the form of a single cell or of many cells, and environmental factors” (Sapp 1987, 7). Since then, the term “epigenetics” has come to be rather mobile, articulated though a range of biomedical fields and approaches. Today, research in this vein is most broadly concerned with what “genes alone do not explain” (Lock 2011, 694).

Waddington is a frequent reference point in review articles and editorials on epigenetics, serving as a means of “colonising the past” (Morrison 2012, 3) that establishes the legitimacy of the field and is suggestive of conceptual and empirical advancement in ways that invite anticipation of developments not yet made. The act of pointing to a lineage implies that “the” origin of epigenetic research is unfamiliar to many scientists; hence it must be a little quirky, a little beyond the mainstream of biomedicine. Yet, simultaneously, through being detailed in high-profile journals such as *Nature and Science*, its legitimacy is nevertheless assured. References to and discussion of Waddington and other long-dead scientists are thus, in this context, central to establishing epigenetics as a form of biomedical novelty (and thus worthy of attention, and perhaps investment), but nonetheless one with a rich genealogy.

The notion that epigenetics is a novel scientific enterprise is further substantiated by (as well as acting as a driver for) the range of initiatives that are currently providing research infrastructure for epigenetic endeavors.³ Such initiatives aim to foster international collaboration, integrate early-career researchers into wider professional networks, facilitate translational research, and coordinate the production of reference maps of epigenomes. These multilateral enterprises are diversely developed through scientists’ own “grassroots” (Satterlee, Schübeler, and Ng 2010, 1041) epistemic activism as well as through “top down” initiatives designed to stimulate innovation through mandating collaboration (cf. Defazio, Lockett, and Wright 2009). In general, these platforms (Keating and Cambrosio 2000) are developed reflexively, and their development often produces strategic responses that are of importance to those trying to understand the dynamics of the epigenetics field.⁴

Such responses are particularly evident in regards to the US American National Institutes of Health (NIH) Roadmap Epigenomics Program, which sparked considerable resistance from within biology. Here, the dynamic and tissue- and cell-specific nature of epigenetic markings was regarded as escaping the static mapping methodologies favored by those building this biomedical platform (cf. Madhani *et al.* 2008). While many scientists seem to agree that the dynamism and specificity of epigenetic changes pose some new and very different challenges to methodology, the existence of established high throughput tools and frameworks for processing large amounts of individual findings across research groups presents the stronger argument in discussions about the direction of funding streams. This instance of platform-building demonstrates very clearly how the field is driven by technology, method and “do-ability” (Fujimura 1987), as well as by the nature of the biological problems at hand. In the process, the scientific problem itself can be reframed, with implications for the identities of the platform, and the knowledge being produced as “novel”.

In situating epigenetics as a form of biomedical novelty, claims-makers must overcome the regularly expressed doubts of their colleagues who argue that it is simply a variant of established research on gene expression (Niewöhner 2011). One way of doing this is through the circulation (in review articles, monographs, popular media and so on) of particularly striking epigenetic investigations that have produced findings that are compelling to scientists and wider publics. Key examples are the experimental animal studies of the research groups around Michael Meaney and Moshe Szyf on the impact of maternal behavior on methylation patterns, as well as epidemiological studies on the effects of the “Dutch Hunger Winter”. Meaney, Szyf and colleagues in Montreal started their experimental work on northern hooded rats from the well-observed “maternal” behavioral features of “arched-back nursing” and “licking and grooming” (Weaver *et al.* 2004). In the wild, rats display these behaviors in a broad spectrum of intensity such that groups of more or less intense arching and licking can be identified in any given population. The initial experimental set-up focused on the effects of these two types of nursing behavior on the methylation status of a stress-relevant receptor in the rats’ hippocampus. Offspring that were nursed by “low” nursing mothers displayed significantly increased methylation at the receptor site compared to “high” nursing mothers. To biologists, this effect confers a higher susceptibility to stress on the affected animal. The effect emerges in the first week of the offspring’s lives, can be reversed through cross-fostering and drug treatment, and persists into adulthood. Further experiments since have shown that effects of this type can be semi-stable across generations and in principle may also exist in humans (e.g. McGowan *et al.* 2009).

Yet, while effects on the germline have been reported for psychiatric phenomena in mammals (Franklin *et al.* 2010, 2011), so far no effects have been shown to be truly stable and persistent into non-exposed generations (Daxinger and Whitelaw 2012). This is understood by many epigenetics researchers to imply the existence of some kind of resetting mechanism, operating in a manner that is beyond current

bioscientific comprehension. The most recent research particularly in plants points to an increasingly complex regulatory network involving not only DNA and epigenetic markers but also a whole range of microRNAs in- and outside the cell nucleus (e.g. Aregger *et al.* 2012; Molnar *et al.* 2010). Researchers now speak of “meta-stable epialleles” (e.g. Rakyan *et al.*, 2002) to refer to the fact that variation occurs above the level of DNA, is stable through somatic inheritance, and has non-deterministic effects on phenotype. Such non-stochastic variations in epigenetic status can be induced by an organism’s socio-material environment. Thus, what emerges here is a molecular science of environmental impacts on mammalian development and reproduction.

Neither the findings on the effects of the environment on biology and health, nor their transmissibility, are new in principle. As Lock (2013) has likewise noted, several statistical analyses in epidemiology have shown similar phenomena. Most prominently perhaps, researchers have shown that the extreme malnutrition of Dutch pregnant women during a clearly defined hunger period in the war Winter of 1944–45 has had an effect on these womens’ grandchildren, increasing their cardiovascular risk (Roseboom, de Rooij, and Painter 2006). The Whitehall II study conducted on civil servants in England to measure the effect of social position on health also clearly showed effects of the social environment on health (Brunner 1997). What Meaney and Szyf are regarded to have added with their proof of principle experimental studies is a clearly defined molecular mechanism for the socio-material environment to have a lasting effect on the human body. Further, their studies have reinvigorated longstanding questions around the transmission and heritability of acquired features.

Today, we can comprehend “new uses of the older concept of epigenetics and a willingness to let the post-genomic world of environmental complexity into the research picture” (Rapp 2011, 678). Debates are playing out within biology as to whether we are seeing “the demise of the gene” (Newman 2013), and hence a (potential) deceleration of research that is underpinned by a gene-centric view of life – though of course such as conception of life was never uniformly accepted in biomedicine anyway (Barnes and Dupré 2008). Yet, technologies of genomics nevertheless helped to (re)produce an understanding of genes as a foundation stone of development, with the fuzziness of “the environment” a secondary consideration. As epigenetics research continues, more interactive and dynamic models are being operationalized within laboratories (Beck and Niewöhner 2006); these introduce new and challenging puzzles for scientists to solve – including what, if any, health benefits for populations could be afforded through epigenetic knowledge production.

Producing promise?

To a limited degree, epigenetic ideas – especially those emerging from or relating to the studies described in the previous section – are also translating into popular

culture, with magazines and popular science books discussing the consequences of research and fuelling further speculation. As one writer of popular science remarks in the provocatively titled *The Epigenetics Revolution*, “we are finally starting to unravel the missing link between nature and nurture; how our environment talks to us and alters us, sometimes forever” (Carey 2012, 7). Often, the findings enrolled in online and print media are results from animal studies, raising questions about what part epigenetics is playing in the mediation of public understandings regarding the relationships between animal and human minds, bodies and (social) environments. More broadly, the instantiation of epigenetic concepts within public discourses provides new resources through which people can “make up” (Hacking 2002) themselves and one another (cf. Bröer and Heerings 2013; Pickersgill, Cunningham-Burley, and Martin 2011).⁵

Yet, the implications of research in epigenetics for science, health and society are unclear. Scientific commentaries and review articles are threaded through with discussions of uncertainties and unknowns: tentative “coulds” and hopeful “mays” commonly steer these narratives.⁶ For instance, the contributions of extrinsic environmental factors on stochastic epigenetic changes are “largely unknown” (Feil and Fragga 2012, 97), the effects of methylation on morphological transitions in insects is “unclear” (Feil and Fragga 2012, 98), and whether temperature-dependent sex determination in a range of animals has anything to do with methylation “remains to be explored” (Feil and Fragga 2012, 98).⁷ Identifying uncertainties as a means of signposting further research that might bear fruit is of course a key function of review articles, and in so doing a means of marshaling symbolic and material resources for particular epistemic agendas (Arribas-Ayllon *et al.* 2010). Nevertheless, it could also be useful to consider whether the embracing of complexity and candid discussions of uncertainty in epigenetics has other origins. In particular, we might speculate that it could reflect a wider tendency within the biological sciences today to move away from the bold assertions of clinical relevance and ontological clarification that have been argued to characterize the discourses of scientists in previous decades (e.g. Borup *et al.* 2006; Hedgecoe and Martin 2008; and references therein).⁸

This is not, however, to say that promissory discourse is invisible within major biomedical fora such as the journals *Nature* and *Cell*. As the abstract of one review paper in *Nature Biotechnology* asserts: “Epigenetics is one of the most rapidly expanding fields of biology”, scientific interest in which “has been accompanied by technological breakthroughs”, and “a comprehensive understanding of epigenetic mechanisms, their interactions and alterations in health and disease, has become a priority in biomedical research” (Portela and Esteller 2010, 1057). The corresponding author of this review – Manel Esteller of the Bellvitge Institute for Biomedical Research, and a holder of various patents around cancer epigenetics – has likewise noted in another review article for *Nature Medicine* that: “We have already entered the epigenetics era” (Rodríguez-Paredes and Esteller 2011, 336).

Cancer especially has been a key locus of research in epigenetics; as was noted in a “Special Section” on cancer genomics in the journal *Science*, investigations are “increasingly focused on the determinants of heterogeneous epigenetic states in tumours” (Suvà, Riggi, and Bernstein 2013, 1570). Studies showing that tumor cells may exhibit altered patterns of DNA methylation have motivated a range of investigations (Das and Singal 2004; Laird and Jaenisch 1996), and the promissory aspect of epigenetics is perhaps most readily discernible in the realm of oncology. Already, various patents around cancer epigenetics have been administered; further, “epigenetic drugs” are now on the market, such as Zolinza, a histone deacetylase inhibitor manufactured by Patheon for Merck. Collectively, these therapeutics had global annual sales of over \$1 billion by 2011 (Visiongain 2011). According to a 2013 “Biobusiness Brief” in *Nature Reviews Drug Discovery*, “recent progress in showing that enzymes involved in epigenetic processes can be modulated by drug-like small molecules, has fuelled interest in exploiting the therapeutic potential of epigenetic targets” (Burridge 2013, 92); some companies are specifically focusing on epigenetic drugs, and GlaxoSmithKline houses a Cancer Epigenetics Discovery Performance Unit operating out of Pennsylvania.

In spite of the interests of the pharmaceutical industry, however, potential treatments for conditions associated with epigenetic mechanisms such as methylation need not necessarily relate to drug treatments and wider processes of pharmaceuticalization (Abraham 2010; Williams, Marin, and Gabe 2011). Rather, the authors of one recent psychiatric study, for instance, assert that their results “support the idea” that particular “epigenetic marks may be changed through psychotherapeutic approaches and that these changes underline changes in cognitive functions” (Perroud *et al.* 2013, 1). Accordingly, existing psychological and environmental interventions may come to find new legitimacy through research in epigenetics (as has been the case in the neurosciences). The sociotechnical assemblages constitutive of the epigenetics field therefore resist easy characterization, and so demand empirical and theoretical attention from social scientists.

Epigenetics and society

Many scientists working in (epi)genetics accept that “genes do not have clearly demarcated beginnings or ends; nor are they stable, and only very rarely indeed do they determine either individuals’ phenotypes or the biological make-up of future generations” (Lock and Nguyen 2010, 336). Such refusal to grant ontological primacy to DNA is attractive to anthropologists and sociologists who have long been critical of various forms of genetic determinism. Epigenetics represents a frontier that it is perhaps especially exciting to explore to those social scientists who remain frustrated by an apparent dearth of attention to the “organic, bodily and environmental aspects and dimensions of human social life” (Benton 1991, 25), as well as to sociologists of the body and of embodiment (Williams, Birke, and

Bendelow 2003). We will discuss this further in the next section; first, though, we must consider what kind of “environment” epigenetics is constructing.

Epigenetic research into health and illness is often concerned with the ways in which “the environment” leaves its mark on the genome, and how this then produces particular phenotypic effects. What actually counts as “the environment” is a complicated question, operationalized in diverse ways across experiments and different spatial scales; as Landecker (2011) shows, even “food is now also a conditioning environment that shapes the activity of the genome and the physiology of the body” (167). Through these wide-ranging but often highly specified constructions of the environment, epigenetics contributes to a “molecularization of biography and milieu” (Niewöhner 2011, 279) that more firmly situates the study of embodied subjects within the purview of laboratory science. The idea of “early life adversity” and its presumed effects is important in structuring some of the experimental approaches to epigenetics. This aligns neatly with contemporary health and social policy discourses, with their emphases on early development, environment and intervention and the biologically malleable human body this entails.

Yet, the social and ethical implications of epigenetics (and especially conceptualizations of “the environment”) have, to-date, received limited attention – though the beginnings of a bioethical discourse are apparent. Barnes and Dupré (2008) have argued that “the extent of the stability of methylation could turn out to have great ethical significance” (93); likewise, Rothstein, Cai, and Marchant (2009) – writing on the ethics of epigenetics in *Nature Reviews Genetics* – regard possible issues pertaining to environmental justice, intergenerational effects, access to health care, and privacy and confidentiality matters as important. In so doing, they co-mingle established and more contemporary ethical concerns, re-embedding late twentieth-century and more recent discussions about “genethics” into a new discourse on the implications of epigenetics (which they seek to shape). Cognizant of some of the mutations in developmental imaginaries potentially being powered by research in epigenetics, political scientist Hedlund (2012) has noted the shifts in responsabilization that could be affected. Debates about the ethical dimensions of epigenetics may prove to be around the responsibilities of states to citizens; this is in contrast to the bioethical commentaries on and analysis of free will and individual responsibility that have been stimulated by other recent work in biomedicine.

Noteworthy in this context is the development, and societal implications, of environmental epigenetics; this can be seen as in part enabled and propelled through a broader molecularization of toxicology (Shostak 2005). As Mansfield (2012) notes, public health and social care advisories from governments or other institutions that draw from such research potentially extend state surveillance and the disciplining of particular groups of actors. In regards to the potential (epigenetically determined) health consequences of eating certain foods that may contain contaminants, for example, women come to be enjoined to “worry about

the effects of chemicals on *future* fetuses” (Mansfield 2012, 359, emphasis in original; see also Landecker 2011). In effect, women are framed through some kinds of epigenetics research *as* the first environment for children, potentially activating and augmenting a range of moral discourses and subjecting them to (increased) scrutiny (Müller and Kenney, in preparation; Singh 2012).⁹

Relatedly, reports on the aforementioned experiments with rats (which found that pups which have been licked less by their mothers become more aggressive and anxious) evoke stereotypical images for female responsibility for their offspring’s fate. As in other (bio)medical fields, it became obvious that also in epigenetics biomedical knowledge and the social structures of parenting, gender and family life mix in a range of ways, sometimes unexpectedly and often in the process creating new ways to be anxious, concerned, and expectant (Browner and Preloran 2010). Accordingly, in spite of Hedlund’s normative suggestion urging that any ethical framework for epigenetics should be concerned with the duties of states, we may nevertheless find that biomedical research in this area will create further ways in which individuals can be responsabilized: in particular, as care-takers of life that does not yet exist.

Recent scholarship on personalized medicine and the racialization of pharmaceuticals (Kahn 2013) also suggests that we must be attentive to the possibility that epigenetic drugs may become targeted to particular populations, reinforcing cultural assumptions about “race” and underscoring the somatic rather than societal aspects of health and illness. On the other hand, however, the arguably stale debates about the “biological” and “social” causes of increased cardiovascular disease in “Black Americans” has moved forward in potentially productive ways through epigenetics; this is used as a means to deconstruct simple biological notions of race and foreground the necessary entanglement of nature and nurture in processes of socio-material change (Kuzawa and Sweet 2009). This further underscores the complexity of delineating and defining social scientific “targets” of critique and intervention.

While determinist readings of epigenetics findings are highly problematic and widely contested, it is also worth noting that some of these resonate with received wisdom both in the social and biological sciences. From an STS perspective informed by the sociology of scientific knowledge (SSK), we might read this as being part and parcel of the processes through which epigenetics research comes to be legitimated and authorized. However, other social scientists might note how some ideas current within epigenetics – such as imprinting – have received strong backing from a range of quarters including epidemiology, psychoanalysis and even certain social theories. Bourdieu’s notion of the habitus, for instance, is suggestive of a view that understands people as “predisposed” to certain milieu and not others. This, we believe, has a variety of implications, emerging from different conceptual bases: for the novelty ascribed to epigenetics, for its cultural traction, for its potential import for health and society, and hence for the kinds of contestation, critique and collaboration that might be expected from social scientists.

Engaging epigenetics and social science

As noted above, some scholars have been encouraged by the resonance between imaginaries of development within epigenetics and sociological theory. Further, epigenetics researchers have argued for the necessity for mutual engagements between biomedical and social scientists; as McGowan and Szyf (2010) concluded in the final two sentences of a recent review article:

[U]nderstanding the epigenetics consequences of social exposures stands not only to revolutionize medicine but also to transform social sciences and humanities as well. Epigenetics could serve as a bridge between the social sciences and the biological sciences, allowing a truly integrated understanding of human health and behaviour.
(71)

Yet, as Lock and Nguyen (2010) note, within the field of epigenetics “networks involving social scientists, social epidemiologists, and basic scientists – formations that might well incite radical change and insights – remain very rare indeed” (338). Such networks may be difficult to establish, not least because of the importance of (co-)developing infrastructure to undergird interdisciplinary work. This will involve, for instance, constructing the material and social scaffolding needed to support research which produces and uses both biological and sociological data.¹⁰

Attempts, however, are being made to produce hybrid communities that can undertake epigenetics research that is responsive to social scientific insights and findings: the UK Economic and Social Research Council (ESRC), for instance, held an “International Challenge Symposium” in Edinburgh in June 2012 on “Social Science and Epigenetics: Opportunities and Challenges” (ESRC 2012). This brought into conversation life, medical, psychological and social scientists to discuss the benefits epigenetics might afford the academy in terms of new understandings of the lived body, actively promoting interdisciplinary approaches. Initiatives such as this – reminiscent of those seen in synthetic biology (Molyneux-Hodgson and Meyer 2009) – seek to enroll investigators into a particular research agenda, and are structured by logics of innovation and ontology (Barry, Born, and Weszkalnys 2008): they seek to both propel sociotechnical change and (co-)produce novel conceptualizations of biosocial entities.

There are challenges such endeavors, however. For their part, biologists may be hesitant to incorporate the complexity of social life and sociological data within their studies, given that the biological systems themselves are not yet well characterized. Moreover, given the current trend towards fast-paced, publication-focused knowledge production in the life sciences, collaboration even within these disciplines is not straightforward (Müller 2012). Social scientists, on the other hand, may also be reticent to playing the role of what many might see as “handmaiden” to life scientists, conforming to an investigative enterprise that they understand as being developed from outside the space of their own intellectual regimes. Further, many working in STS, sociology, anthropology and other disciplines will be

sensitive to the social assumptions and implications (as discussed above) that are embedded within and emerge from epigenetics.

Assuming the concerns of social scientists and humanities scholars around the production, circulation and (potential) reception of epigenetic knowledge are reasonable, however, is in fact itself a good reason to engage in collaborative enterprises with life scientists. Partnerships and mutual engagements between technoscience and social science are increasingly common – part of and mobilized by a wider “interventionist turn in science and technology studies” (Allhutter 2012, 684) – with a range of alliances between STS practitioners in the fields of IT, nanotechnology and synthetic biology currently underway. Collaboration between epigenetics and social science might likewise afford benefit to the disciplines involved. How such collaboration might progress remains an open question, though both empirical and conceptual approaches from the social sciences might be useful in epigenetic studies, and epigenetic biomarkers might be instructive to include in social scientific health research (Timmermans and Haas 2008). In participating in such interdisciplinary research, we might consider the wide-ranging engagements social scientists have had with genetics (e.g. Freese and Shostak 2009), including through the sharpening of explanatory models of biosocial interactions, their somatic effects, and societal consequences (see also Von Scheve 2011). While overly simplified deterministic readings of epigenetics are, we feel, to be avoided, some social scientists may willingly embrace the intellectual challenge of innovative concepts that are able to deal with the situated entanglement of material and social elements within processes of human development. Engaging critically in, for example, processes of translation – particularly with regards to social, welfare and health policy – might also provide a niche for a social scientific contribution that may be seen as essential by public and private funders.

As an authorial collective, we each have different viewpoints on these matters, with our own normative assumptions, stakes and aspirations. Accordingly, we do not advocate *a* way for social scientists to treat or work with epigenetics; rather, we consider that a range of approaches – social science “in” or “of” epigenetics (pace Straus 1957) – are most likely to bare intellectual fruit. We are somewhat reluctant to follow the rather breathless calls to reinvigorate social science through collaboration with life scientists that can be heard in certain quarters – not least because what, exactly, it is about the social sciences that is so lacking in vigor is seldom explicated. Further, we remain reflexively aware of the diverse ways in which biomedical promises can shape social scientific research agendas (Hedgecoe and Martin 2008). Nevertheless, we are keen for investigators across disciplines to consider seriously what is at stake through interdisciplinary endeavors, and the degree to which these have the potential to enrich their scholarship, whilst also remaining attentive to the normative outcomes we are likely to have a role in producing (Singh 2012).

Although it is not our intention in this paper to outline an agenda for social science and epigenetics, we would like to discuss in just a little more detail the

place of public and policy engagement in epigenetics. Given the engagement roles that STS scholars regularly occupy when in intimate association with technoscience, how this might progress is useful to consider. Social scientists involvement in public engagement about contemporary developments in science is one route through which they are able to contribute their professional expertise in the public domain. Such engagement can generate critical space and dialogue, highlighting complexity, uncertainty and ambivalence (Kerr, Cunningham-Burley, and Tutton 2007). Working with scientists to promote sociologically informed public engagement can provide an alternative to a marketization of public engagement, where dialogic events are commissioned to specialist organizations. While successful and professional enterprises, they tend to operate with temporary affiliations to specific scientific developments or teams and by necessity with a shorter-term view and narrowly defined outcomes. Notwithstanding the on-going debates about “public sociology” (Burawoy 2005; Calhoun 2005; Tittle 2004), we suggest that we need to maintain social scientific perspectives and presence within public and policy discussions, bringing normative energy to our activities without narrowly specifying outcomes. In addition to the oft-rehearsed mantra to move public engagement upstream, we propose too that attention should be paid to potential *downstream* effects, in terms of the trajectories of the translation of epigenetic research into policy and practice (for example, through therapies and the practices of health care they may enjoy).

In sum, then, we cannot “predict where a focus on epigenetics in a postgenomic world will lead our life scientists” (Rapp 2011, 678) – nor can we assert with confidence what kinds of wider shifts in medicine and society we will see as a consequence. Social scientific engagements with this area of research, however, have the potential to shape the new territory being explored; hence, the ways through which collaboration and critique might and should play out require reflection. Lessons from social scientists’ engagement in other areas of biomedicine – e.g. genetics and genomics, regenerative medicine, synthetic biology and neuroscience – suggest that our roles will be freighted with different expectations from our peers, life scientists, governments and industry, and the “insider/outsider” position familiar to many empirical researchers will prove challenging as well as creative.

Discussion

In light of the promissory aspect of epigenetics, it is perhaps not surprising that the attention of humanities scholars and social scientists has begun to be attracted by developments in this field.¹¹ Some commentators have found cause for optimism in the multimodality of epigeneticists’ developmental models (e.g. Nicolosi and Ruivenkamp 2012; Papadopoulos 2011). These certainly appear to suggest the need for revisiting social scientific theories of embodiment, habitualization and the reproduction of social inequality. Yet, even apparently complex developmental

imaginaries may nevertheless contain implicit assumptions about the nature of social life, which may warrant questioning. The hopes and fears that might adhere to epigenetic discourse imply different roles, and responsibilities, for STS scholars (and those of related disciplines, including health geography, environmental sociology, queer studies, and so on). Epigenetics might usefully be considered both as a “case” through which to explore sociological themes – such as biomedicalization (Clarke *et al.* 2010), biopolitics (Lemke 2011), and expertise (Collins and Evans 2007) – and as an area of import in its own right (or, in Williams’ (2011) terms, as both a “prism” and a “problem”). In the latter instance, social scientists could actively seek to influence the development of epigenetics by critically engaging with scientists, as well as wider publics (Cunningham-Burley 2006) and the actors and institutions constituting the sociotechnical spaces inside which investigations operate.

In spite of the novelty ascribed to epigenetics, the field also builds on established genome sequencing technologies and infrastructures. We might, then, reflect on Landecker’s (2010) recent warning to scholars of biomedicine and society:

A problem that arises with accepting high-profile entities or practices as given categories of analysis or boundaries of research projects is that one can easily mistake the thing as the origin of the phenomena which follow it or accompany it in the discourses under study. (220)

Fields, practices or conceptualizations that might appear uniquely novel or transformative may instead turn out to be “just one of many outcomes of a systematic change” in research technique (Landecker 2010, 221). Landecker suggests therefore that analysts might more fruitfully focus their attention to the methodological and infrastructural context within which objects of (temporary) prominence emerge. Her point is well taken; however, we also regard the construction of novelty itself as a pertinent, and potentially conceptually and empirical rich, point of departure for social scientific analysis (Pickersgill 2013). If epigenetics is taken by some to be “one of the most promising and expanding fields in the current biomedical research landscape” (Rodríguez-Paredes and Esteller 2011, 330), then the logics underlying this are worth mapping; so, too, are the contexts and instances where such celebratory discourse is accepted, rejected, or even ignored (Pickersgill 2013; Stadler 2012).

Finally, we suggest that it will be useful to reflexively consider how the societal dimensions of epigenetics are themselves being performed through social scientific analysis. Extending our reflections on how we turn “epigenetics” into a “case” for STS research, we need to ask: what ontological work is necessary when we place boundaries around forms of epigenetic praxis in order to render it amenable for our inspection, and to what end? Further, how appropriate is it to translate concepts and ideas developed in, for instance, the social studies of genetics and neuroscience for the analysis of epigenetics (see Rappert 2007)? The translation of analytic strategies and explanatory frameworks between different case studies is not an “innocent”

activity; it enacts the world in particular ways (cf. Law 2004). Our conceptual and methodological agendas shape the nature of our research and its implications, and these are themselves contoured profoundly by wider disciplinary debate (and, indeed, fashion): as Wyatt and Balmer (2007) note, within STS “there can be a moral pressure to relate ‘micro’ level work to the ‘bigger picture,’ and, on the other hand, there can be a zealotry associated with doing microlevel, case study work” (622). These and other approaches will shape social scientific engagements with epigenetics in important ways. In light of the emergence of social and biomedical research around “epigenetics”, we might regard this as a timely case through which to consider the nature of caseness itself. In this way, STS analyses of epigenetics may more easily resist complaints of being “just another case study” (Beaulieu, Schanhorst, and Wouters 2007).

Conclusion

Research in epigenetics is gaining widespread attention in a range of spheres, including the social sciences. The production of epigenetic knowledge is related to new and established technologies, tools and methodologies, rapidly growing public and private investment (such as (inter)national research programs to develop epistemic infrastructure), and increasing numbers of publications. Significant questions remain to be addressed in light of this: how is epigenetics being imagined and developed; what forms of knowledge, practices and applications are considered salient; and how are these being compared and related to genomics? Further, what notions of society and social groups are implicit within research and materialized through it; how will political and clinical gazes be (re)orientated through recourse to epigenetic imaginaries; and what kinds of social and ethical responses will be appropriate in light of any ensuing shifts in policy and practice? More reflexively, what role can and should social scientific commentators play through attending to these diverse issues: “advocates, intermediaries, translators, connoisseurs, critics, activists” (Calvert and Martin 2009, 201) – or perhaps better yet, all of these? The answers to these questions have implications for the kinds of networks that can be built to propel social scientific and biomedical innovation, and the policy and clinical dimensions and consequence of it. As such the issues outlined here merit further reflection and consideration.

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Notes

1. Today, prominent researchers such as Bird (2007) and McGowan and Szyf (2010; see also Bollati and Baccarelli, 2010; Richards, 2006) argue that it is not scientifically useful to restrict the definition of epigenetics to include only the study of markers and processes that are heritable.
2. This talk is currently somewhat muted, and primarily restricted to STS-fora, though certainly publications and conference presentations bringing in discussions of epigenetics are increasing.
3. Satterlee (a senior scientist at the US NIH), Schübeler, and Ng (2010) have summarized some of the infrastructural projects currently fostering research into epigenetics; these include: The Australian Epigenetics Alliance, the European Epigenome Network of Excellence, the NIH Roadmap Epigenomics Program, and the International Human Epigenome Consortium
4. By “reflexively”, we mean here not simply motivated by common interest in a field but rather in full awareness of epistemic cultures and conflicts, competitors and funding streams.
5. Notably, though, the expectations and emphases apparent within more popular discourse on epigenetics – which focus on the heritability and environmentally determined aspects of epigenetic modification – are more contested within the scientific literature. This should come as no surprise to STS scholars, but it does underscore the importance of continued sociological examinations of the material and rhetorical vehicles by which emergent knowledge travels between discursive arenas.
6. See, for instance, Feil and Fraggia (2012), Houston *et al.* (2013), Jirtle and Skinner (2007), and Satterlee, Schübeler, and Ng (2010).
7. Indeed, even the prominent experimental work cited above has been subject to critique by other scientists.
8. However, the existing STS literature on the dynamics of expectations does acknowledge that the promises made by funders and other institutions do not necessarily match the more modest hopes of individual scientists (Pickersgill, 2011).
9. Such framings resonate with discourses associated with the so-called Barker or “thrifty phenotype” hypothesis (Barker, 1990; Hales and Barker, 1992).
10. This is a relevant issue for other interdisciplinary ventures, some of which have implications for sociological research itself; see, for instance, Halford, Pope, and Weal (2013).
11. We use the somewhat teleological phrase “begun to be” advisedly but, we think, fairly, given the great degree to which STS and bioethics has been responsive to highly-visible developments in science and medicine.

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